



George C. Marshall Space Flight Center
ER42 Fluid Dynamics



Space Launch System Scale Model Acoustic Test Liftoff Results and Comparisons

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Background



- NASA is developing the Space Launch System (SLS)
- Pre-test liftoff acoustic (LOA) environments predicted with assumptions based on 6.4% Space Shuttle and Ares I Scale Model Acoustic Tests
- Scale Model Acoustic Test (SMAT) implemented to verify predictions
 - Marshall Space Flight Center (MSFC) East Test Area Test Stand 116
 - 16 hot fires April to December 2014

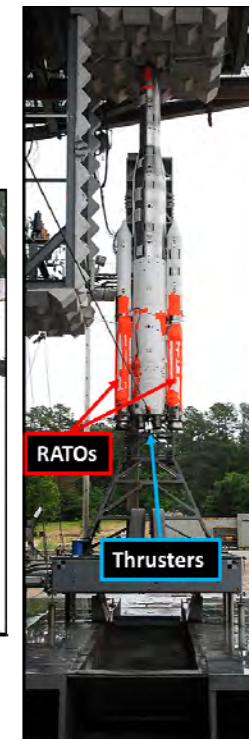
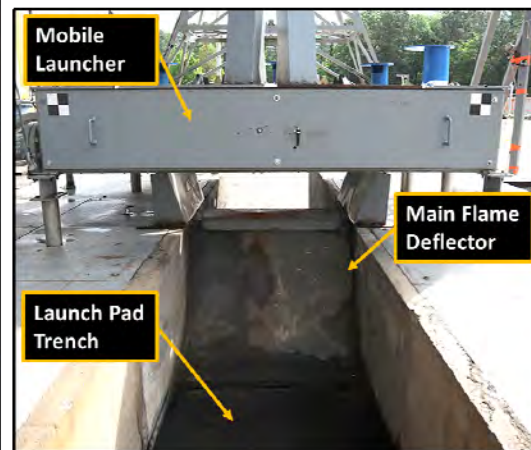
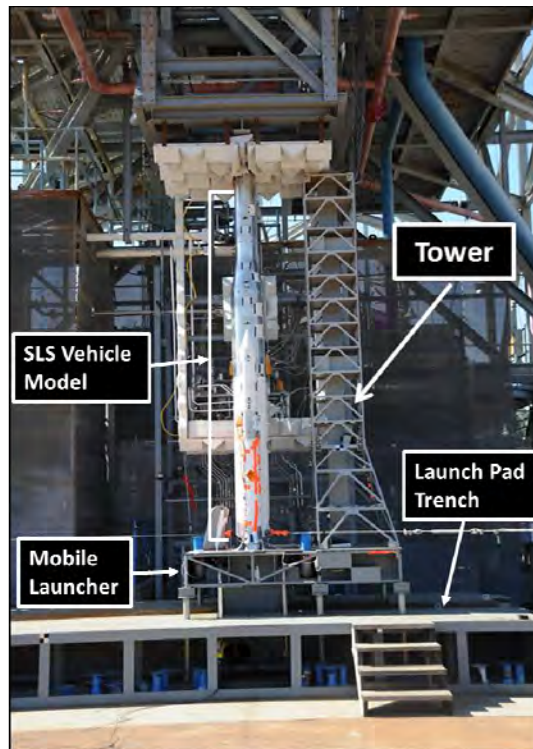




SMAT Objectives & Test Article



- Assess how LOA environment changes with vehicle elevation
- Assess water suppression systems for hold-down and elevated cases
- Assess above-deck water sound suppression system effectiveness at different flow rates
- Compare SMAT above-deck water sound suppression results with ASMAT and 6.4% Space Shuttle Test





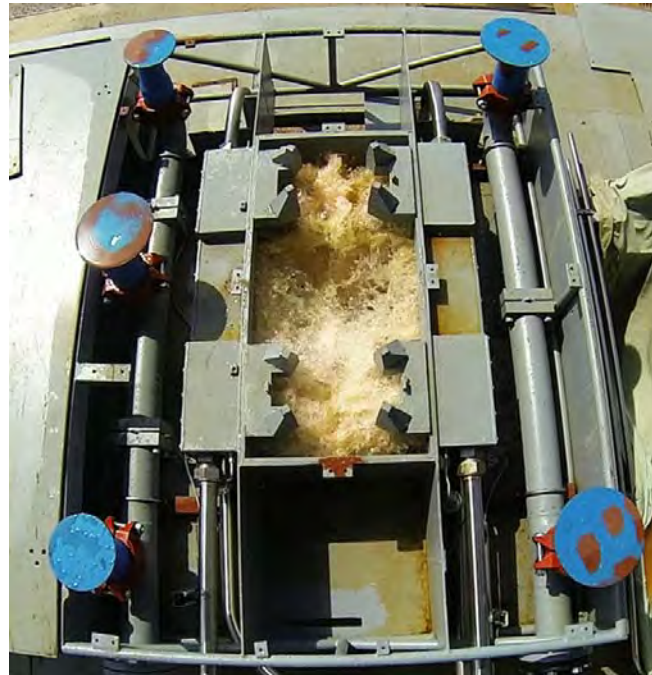
Water Sound Suppression Systems Below & Above Deck



Trench



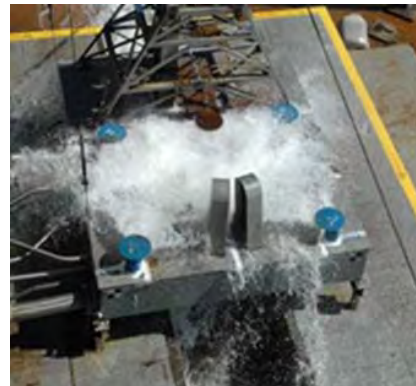
Duct & 5 Nominal Rainbirds



Rainbirds

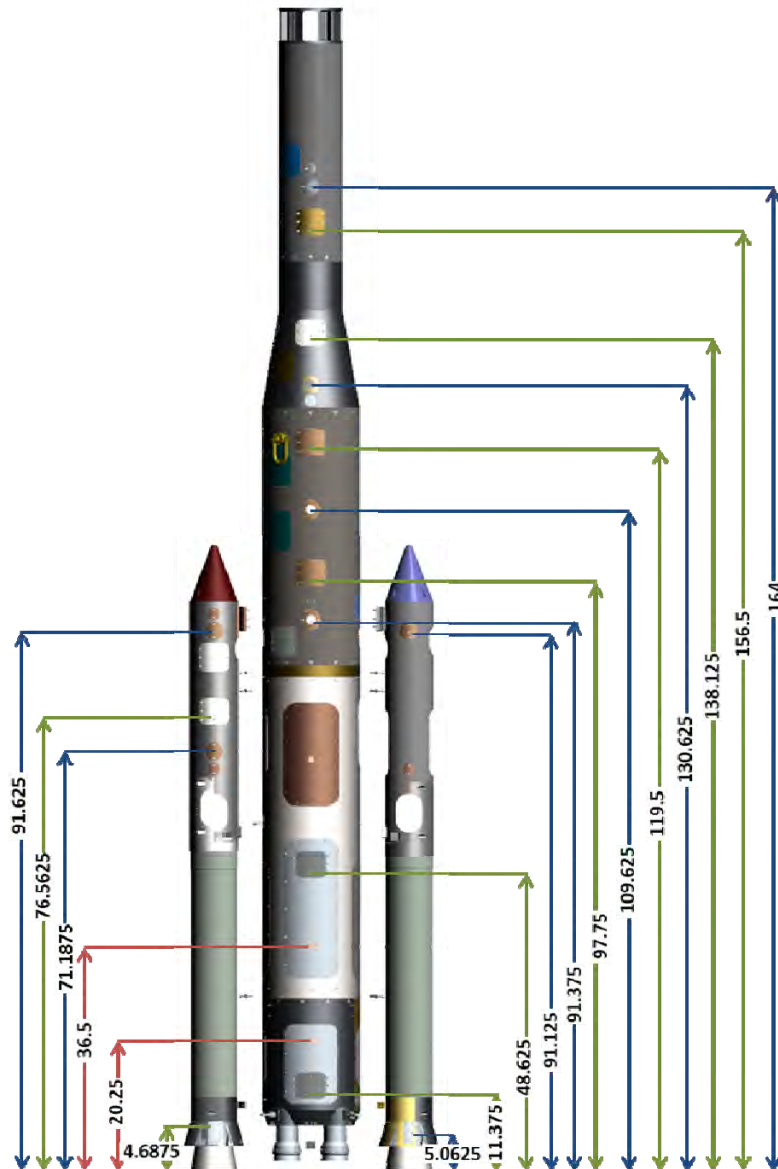
Design / Test
Trade Space

- 4 Rainbirds
- Taller Rainbirds





Instrumentation



Three instrumentation suites:

- Liftoff Acoustics
 - B&K 4944-B microphones
- Ignition Overpressure
 - Kulite XTL-123B-190-30SG & -65 SG
- Spatial Correlation
 - Kulite XCEL-12-100-2D

Data Acquisition:

- 4000 sps
- 256,000 sps

Data Analysis Window:

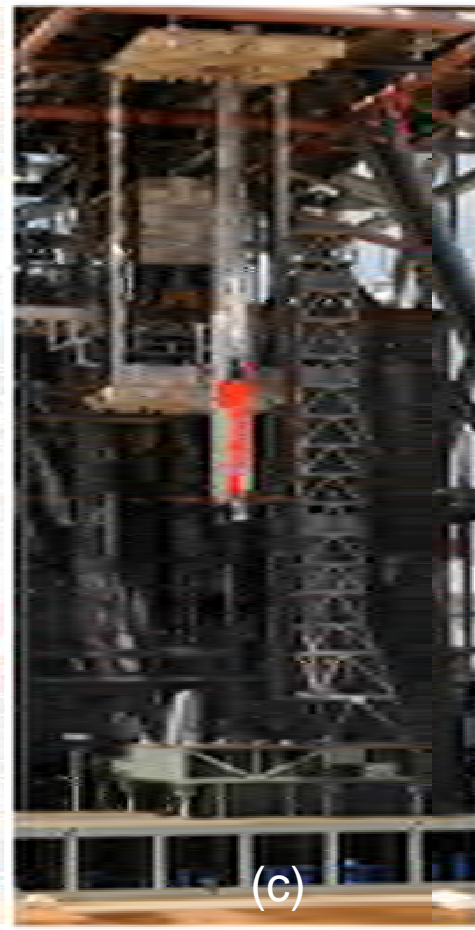
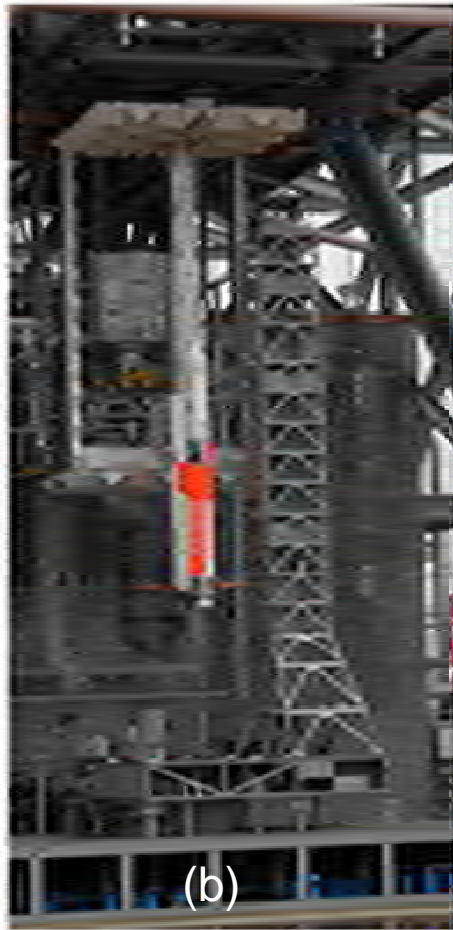
- 1 second



Simulating Liftoff



- SMAT model elevated at liftoff positions:
(a) 2.5', (b) 5.0', (c) 7.5', and (d) 9.0'

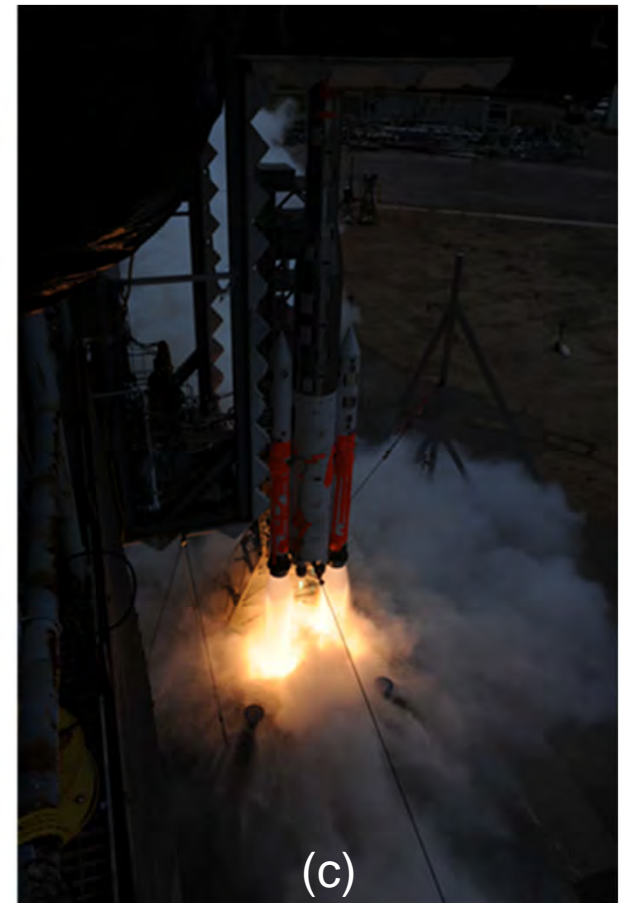




Systems Operations

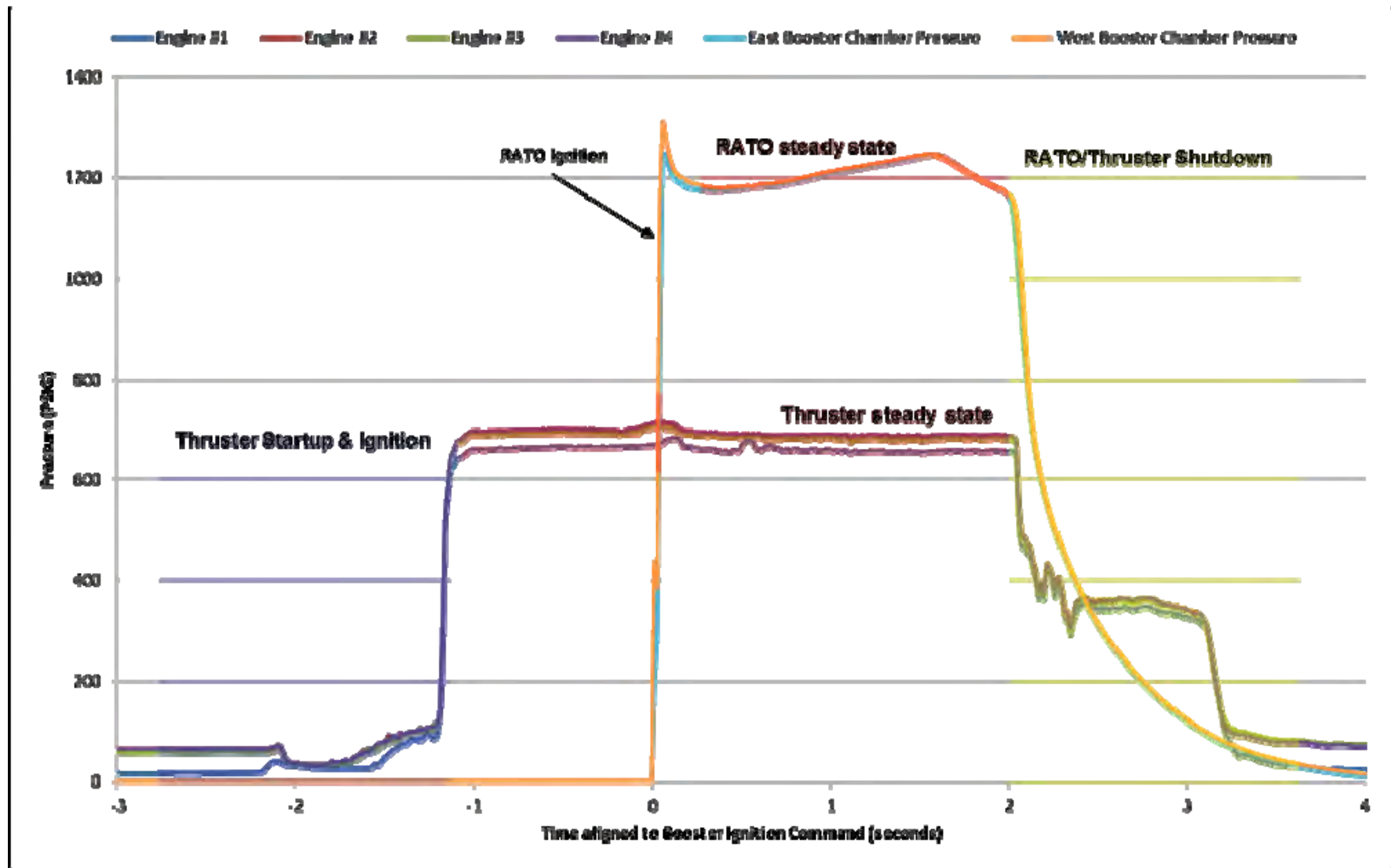


- Operation of the propulsion systems:
 - (a) Rainbirds operational at full flow rate
 - (b) Liquid engines ignited and ramped to full power
 - (c) RATOs ignite and run simultaneously with liquid engines





Data Analysis Windows





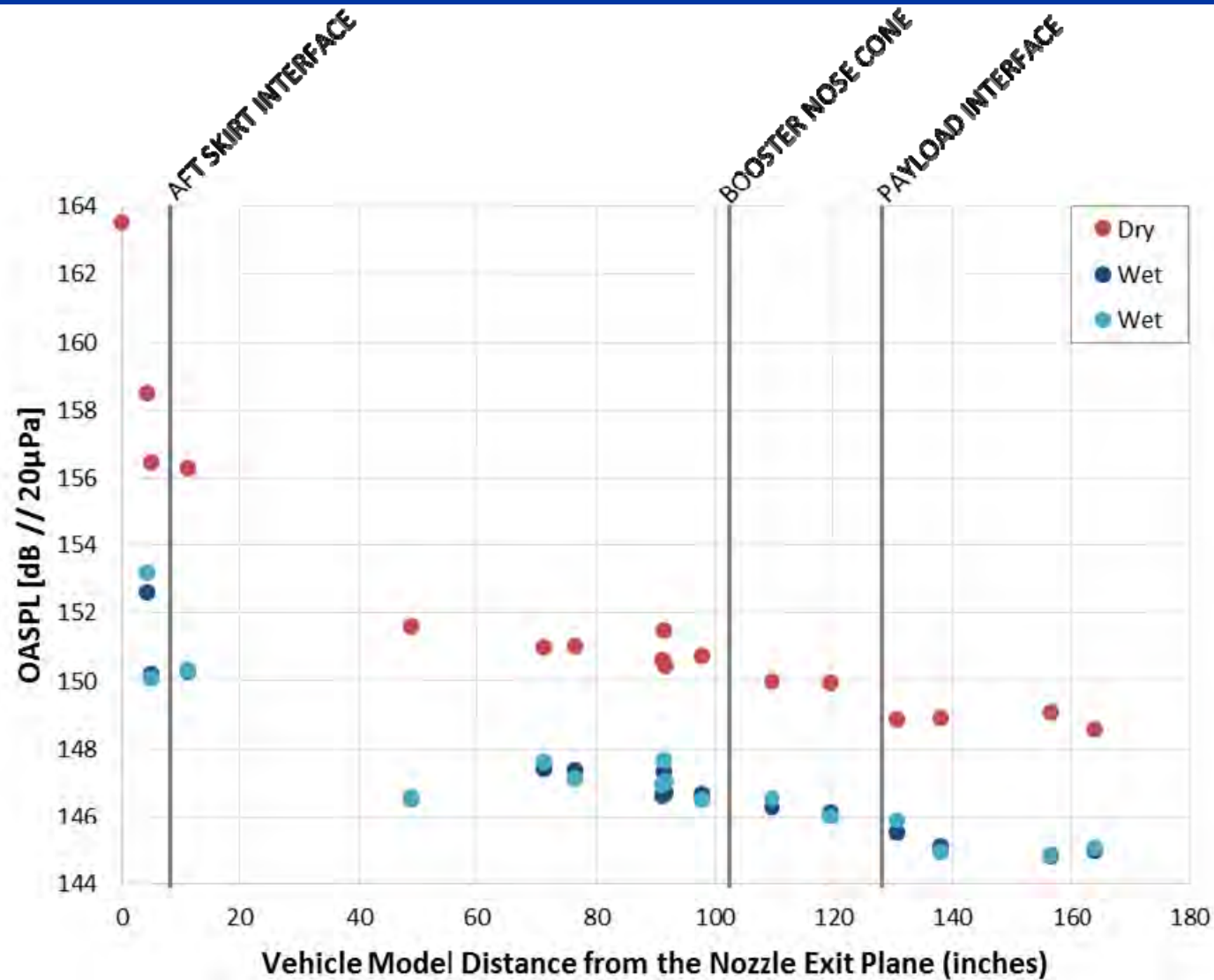
Measuring the Event



- Movies



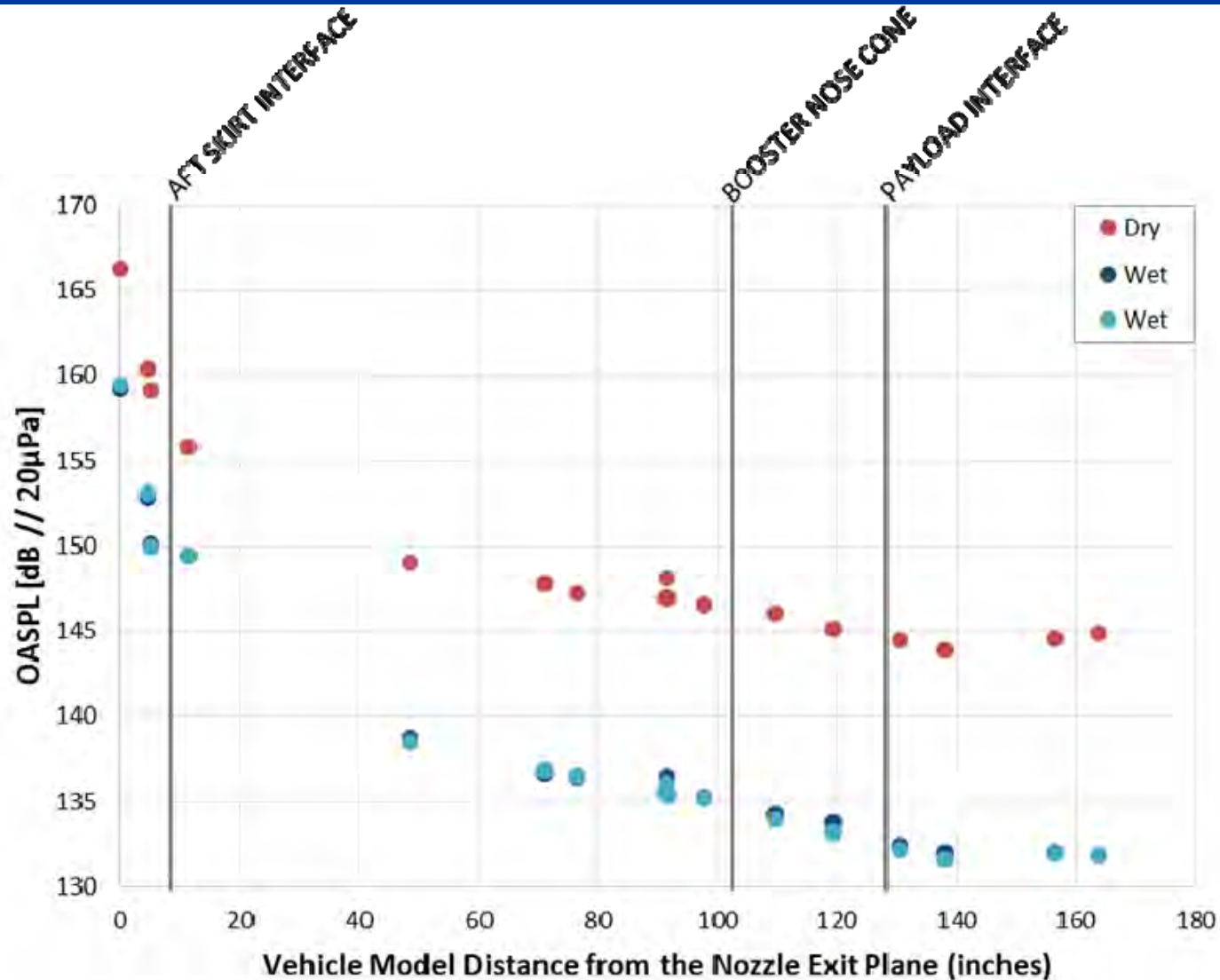
Repeatability



2 wet tests to
determine
repeatability
-Less than 1 dB
difference



Hold Down Noise Levels

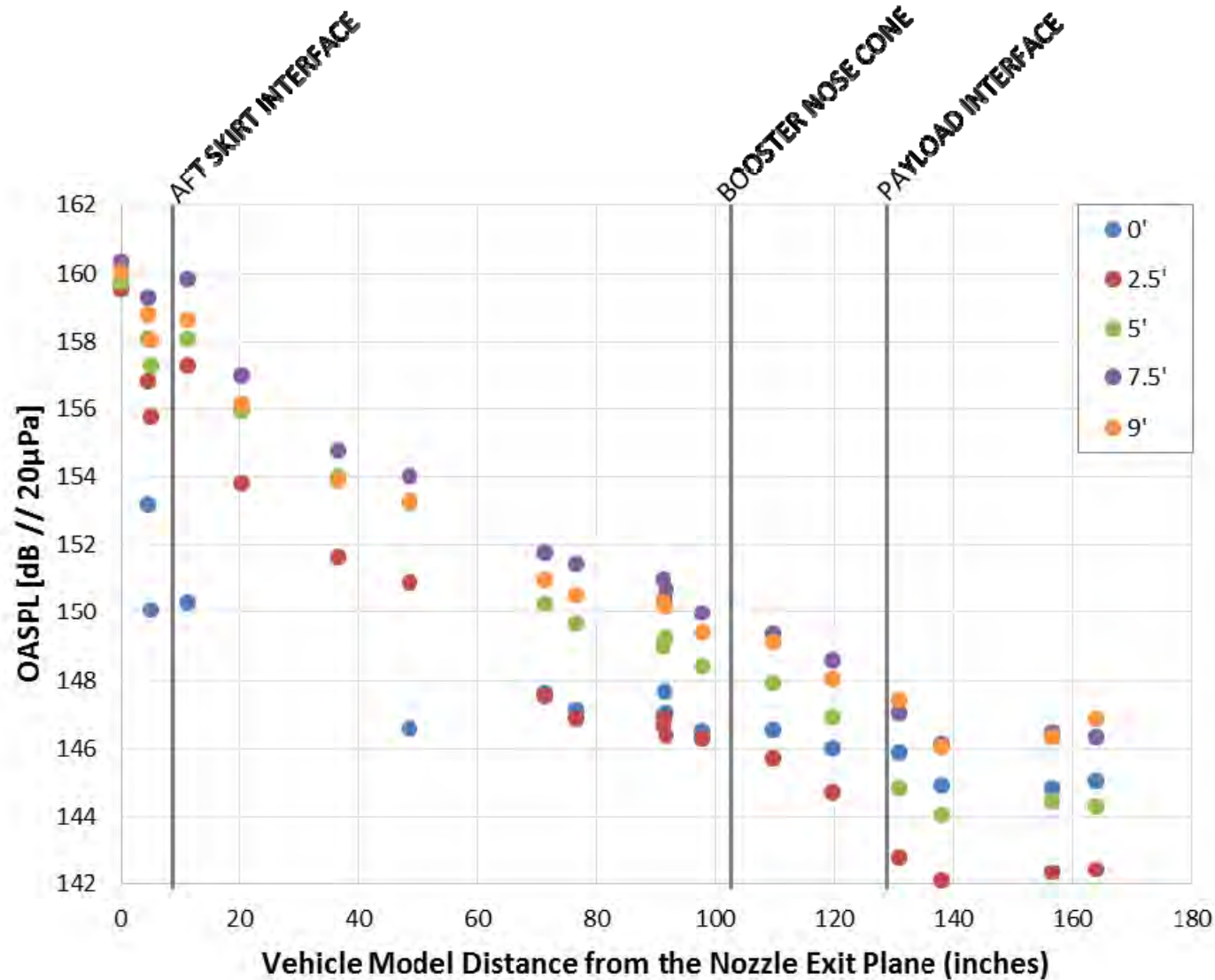


Important for ground equipment such as umbilicals

Addition of water in the exhaust hole and trench reduces overall sound pressure level (OASPL) by ~10 dB everywhere on vehicle



Liftoff Noise Levels

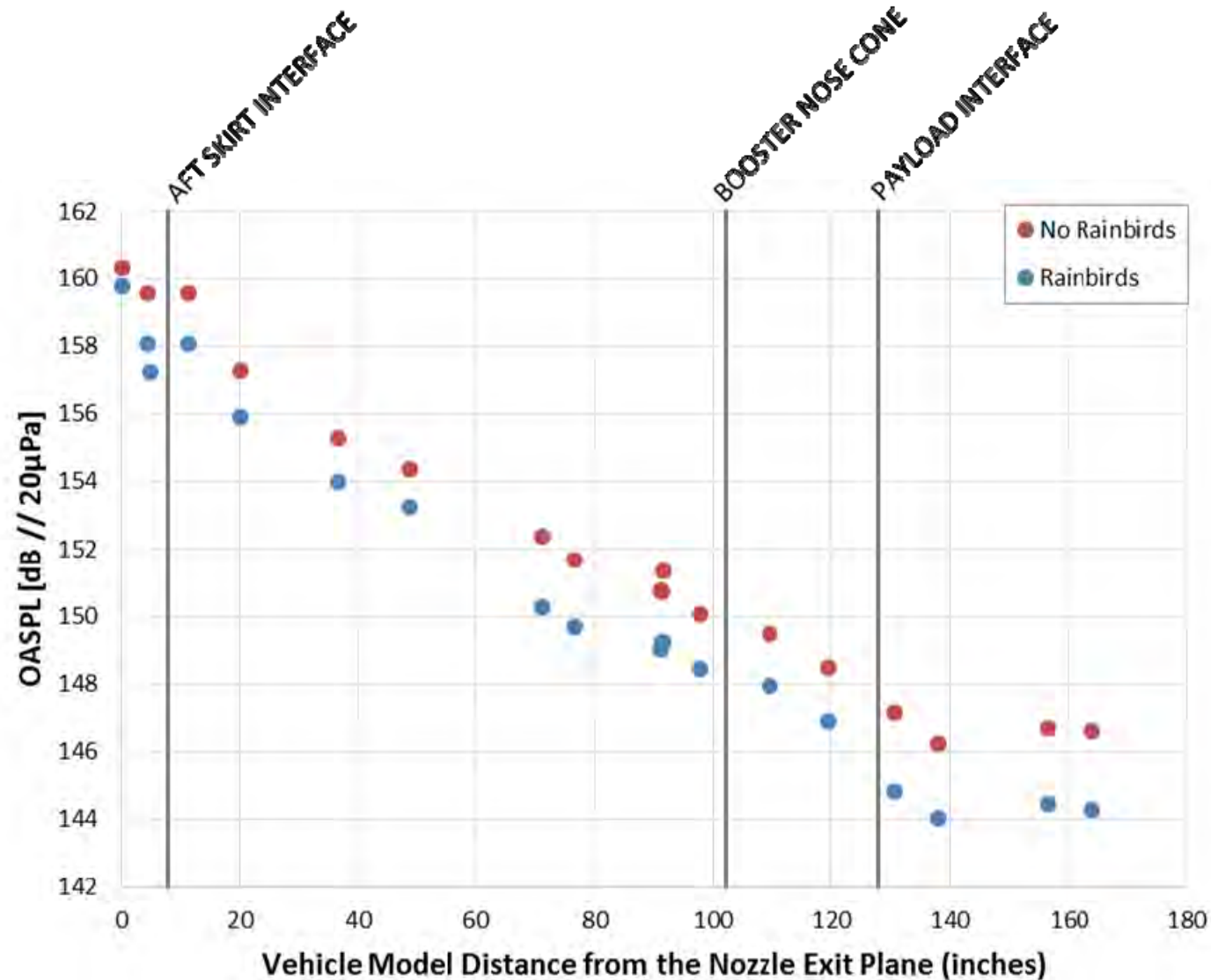


The highest OASPL was measured at the 7.5' elevation

As the vehicle continues to liftoff, the OASPL drops



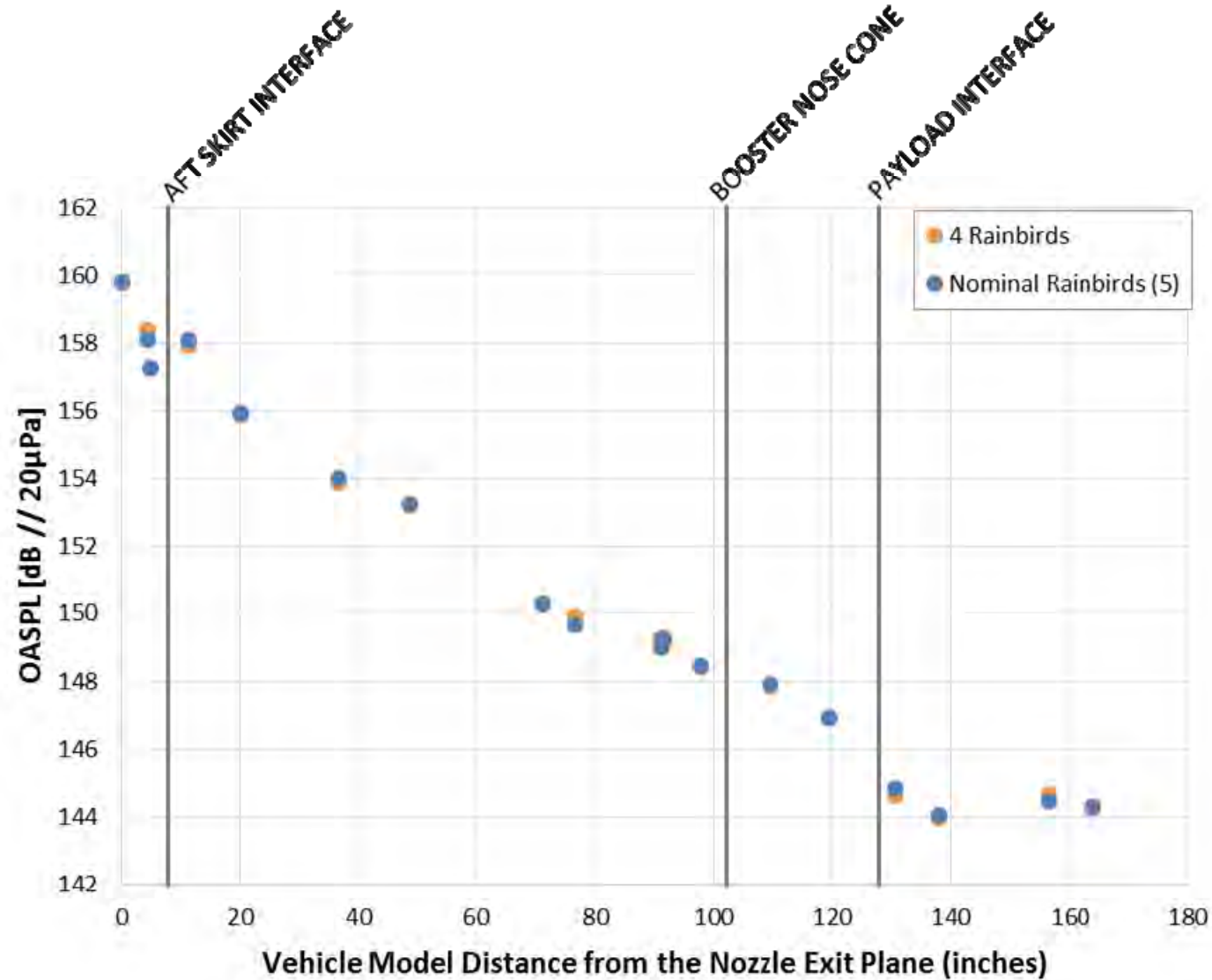
Noise Reduction Results Rainbirds vs No Rainbirds



Inclusion of rainbirds provides a ~2dB decrease in OASPL over entire vehicle



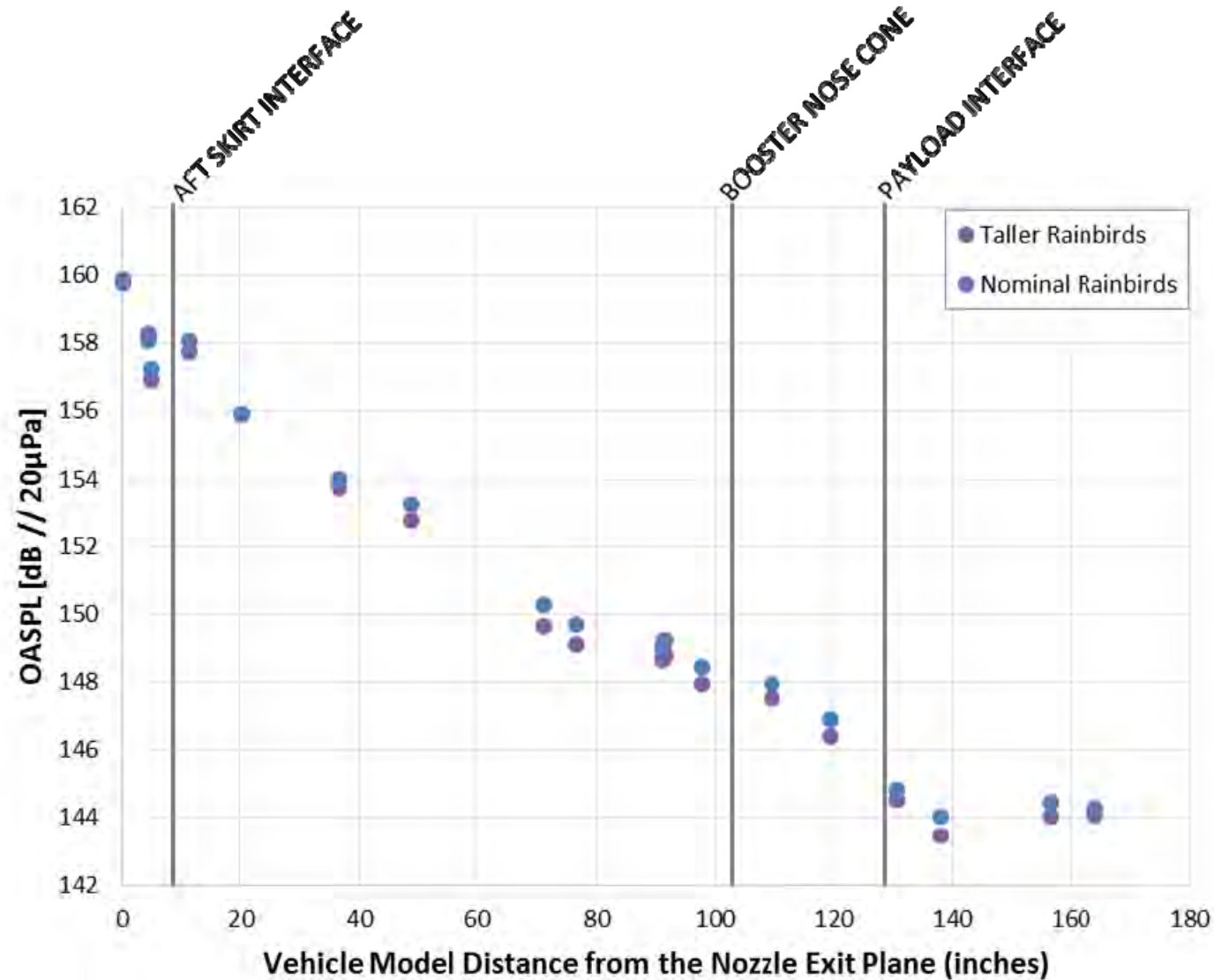
Noise Reduction Results 4 vs 5 Rainbird Nozzles



Removing a rainbird and increasing the flow to the nozzles on the same line does not decrease the OASPL



Noise Reduction Results Taller vs Nominal Rainbirds

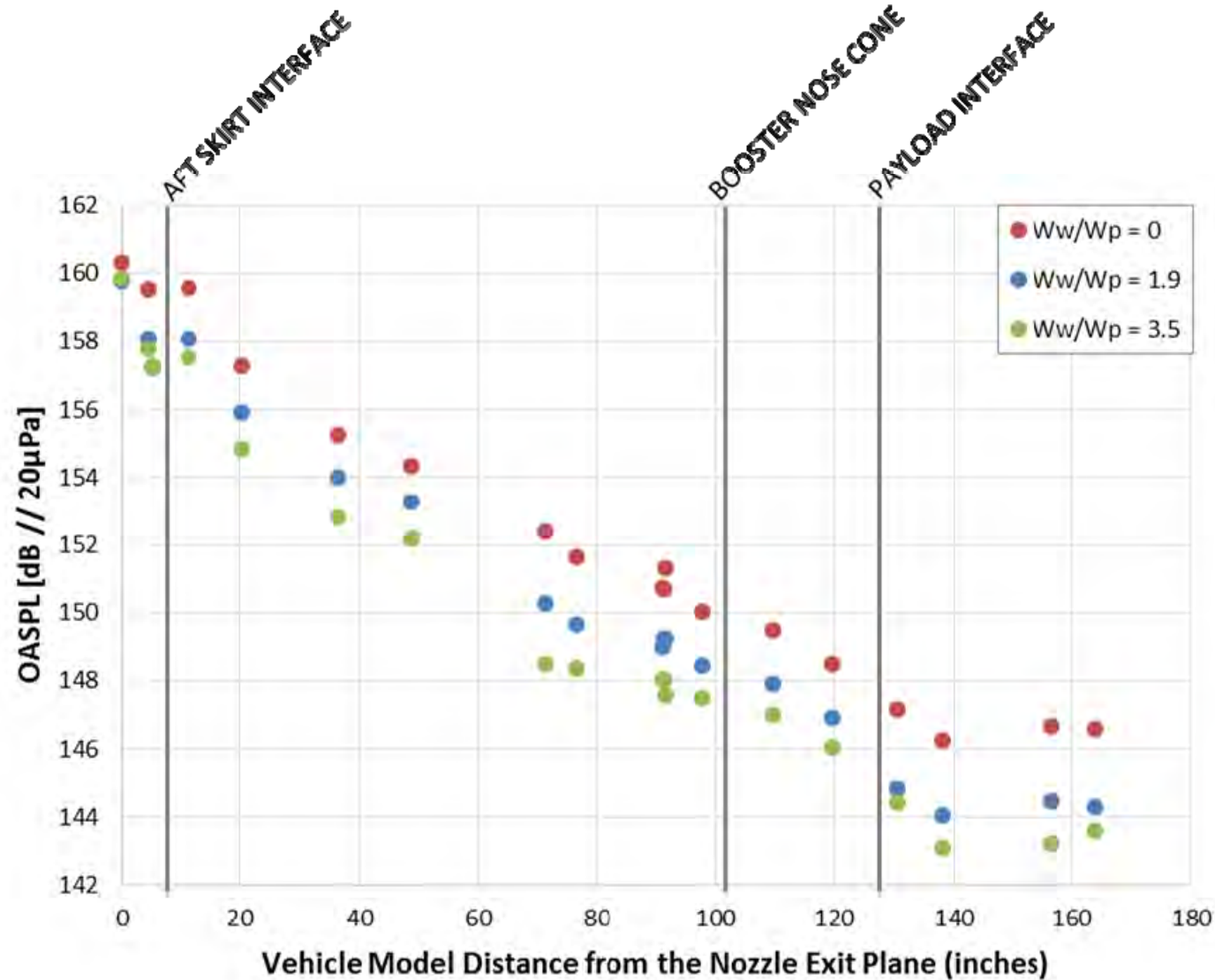


Making the rainbirds taller does decrease the OASPL by ~ 0.5 dB

Reduction not enough to warrant recommendation for design change



Noise Reduction Results Comparison of Flow Rates

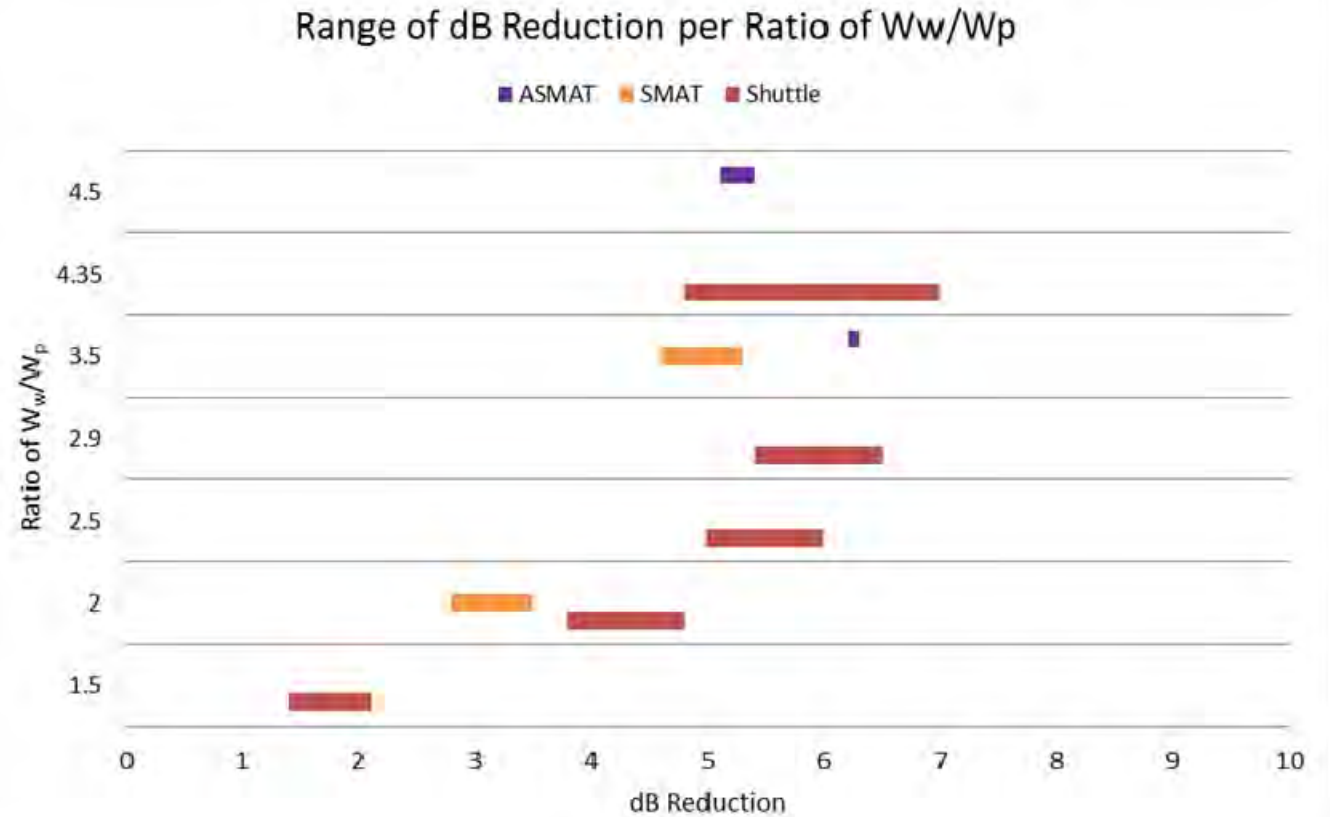


Available water tower and design allows for nominal $W_w/W_p = 1.9$

Increasing flowrate to $W_w/W_p = 3.5$ provides ~1dB decrease in OASPL at locations above 20" on vehicle



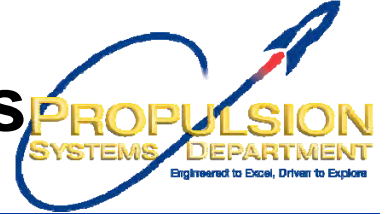
Scale Model Test Comparison



- More water does not necessarily mean more sound suppression
- Rainbird water has highest effectiveness at $W_w/W_p = 3.5$



Conclusions & Recommendations



- Scale Model Acoustic Test allowed for:
- Simulation of liftoff conditions allowing for determination of elevation at which maximum SPL occurs: 7.5'
- Simulation of water sound suppression systems
 - Determined the best solution within the trade space
 - 5 nominal rainbirds
 - Showed that available flow rate reduces the noise
 - But not optimal compared with other scale model test results
- Recommendations
 - Ratio of 3.5 for rainbirds provides best noise reduction
 - Scale model testing is useful for design of launch vehicles and water sound suppression systems